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# A Theoretical Review on the Preventive Measures to Landslide Disaster Occurrences in Penang State, Malaysia

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## Abstract

Based on the frequently unanticipated occurrences of natural landslide disaster across Malaysia, it can be seen that Malaysia is still not fully prepared for occurrences of natural landslide disaster. The lack of predictive and warning systems for the disaster in the country is creating panic and apprehension among citizens alongside with both economic and property losses. The general objectives of this research are: to identify the meteorological factors that cause landslide natural disaster occurrences in Malaysia and to suggest a predictive model for landslide disaster occurrence in Malaysia. This research therefore explored modelling disasters occurrences in order to predict, warn, and prevent huge impact of landslide disasters in Penang, Malaysia. This research shall make use of past literatures and data from Malaysian Meteorological department considering climatic parameters such as daily mean temperature and daily rainfall only. Data mining and Artificial Neural Networks (ANN) shall be suggested to predict landslide disaster occurrences in Malaysia. Thus, the need for a predictive model for occurrence of landslide natural disaster is imperative to the safety of lives and protection of both environmental and economy of the region.

**Keywords:** Landslide; Natural disaster; Artificial neural network; Malaysia; Predictive model.

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## 1. Introduction

The recent landslide natural disaster events in Malaysia have thrown the larger society in apprehension most especially the academic community. This is because nowadays there are frequent unanticipated occurrences of landslide natural disaster across Malaysia which is common in states like Penang, Pahang, Selangor, Kuala Lumpur and Sarawak. For instance, the State of Penang witnessed double unanticipated landslide natural disaster occurrences within year 2016 alone. The first occurrence of landslide natural disaster in Penang for 2016 took place on October 18<sup>th</sup> at Jalan Tun Sardon Penang where many residents of the area were displaced. The second landslide natural disaster occurrence took place on early morning of November 7<sup>th</sup> about one week after Deepavali festival which affected over 400 people. This occurrence cut off the region of Teluk Bahang from the main city which caused loss of properties and disrupted SPM examination. One of the causes of landslide is heavy rainfall which results to flood and consequently lead to landslide natural disaster. According to [Saifulsyahira et al. \(2016\)](#) over 7,965 flood evacuees were displayed from their homes in the state of Sarawak, Malaysia.

Based on these frequently unanticipated occurrences of landslide natural disaster across Malaysia, it can be seen that Malaysia is still not fully prepared for disaster landslide natural disaster occurrences. This is because there is a lack of studies on landslide natural disaster occurrence in Malaysia. This makes Malaysians less prepared when disasters is about to occur and making many individuals not to know what to do during landslide natural disaster occurrences. The lack of predictive, alter and warning systems in the country is creating panic and apprehension among citizens which is also causing both economic and property losses. To prevent, avoid and minimize occurrence impact of the landslide natural disaster, there must be an identification and estimation of landslide disaster with necessary precautions.

## 2. Literature Review

To understand fully the concept of landslide, its occurrence and issues surrounding the disaster, it is very important to discuss the previous studies on the area. There are few studies in the vast literature that investigate issues of natural disaster management such as [Tseng and Chen \(2012\)](#) and [Lin and Pathranarakul \(2006\)](#). Likewise, few studies have specifically investigated issues of natural disaster management in Malaysia such as [Osman \(2016\)](#), [Yusof et al. \(2016\)](#) and [Saifulsyahira et al. \(2016\)](#). It can be seen that the majority of literatures focus on support

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system (Saher and Pathak, 2015), information awareness (Yusof *et al.*, 2016); and victim behaviour (Ali P. A. *et al.*, 2016).

Furthermore, numerous studies have been researched using geographical information system (GIS) on the evaluation of landslide disasters. Guzzetti *et al.* (1999) made a summary of many evaluation studies on landslide hazard. In the recent time, probabilistic models have been used in different studies for evaluation of landslide hazard (Akgun *et al.*, 2008), (Clerici *et al.*, 2002). In different part of the world, the models of logistic regression have been used to map out landslide disaster (Tunusluoglu *et al.*, 2008). The geotechnical and safety factor model have been implemented by many studies (Youssef *et al.*, 2009), (Zhou G. *et al.*, 2003). Using GIS for landslide evaluation with the inclusion of artificial neural network models and data mining using fuzzy logic have been equally applied in other areas (Ercanoglu and Gokceoglu, 2002). On the other hand, little attention is given to the combination of prediction, warning, and prevention which are critical in the averting of the impact of natural disasters. It is not only important to forecast meteorological occurrence; however, it is most important to have a system that predicts, warn, prevent and manage natural disasters even before these disasters occur. Hence, this study explored modeling disasters occurrences in order to suggest the most reliable predictive model that can warn and prevent huge impact of natural disasters.

## 2.1. Landslides Occurrence in Malaysia

In most parts of Malaysia, landslides are recurrent disaster where they pose serious challenge to the structure and settlement that support transportation. In some cases, they result to loss of lives. In the most recent years from 2000 to 2009, damage to property and people were particularly high. Sassa (2008) stated that occurrences of landslide have led to number of significant losses of livestock, properties, highways and waterways. Other places also have record of landslides but relatively low in slope areas while most of the occurrences are on embankments or cut slopes along the road and highway in mountainous areas. Cheng *et al.* (2008) added that landslides were also reported near residential areas and high-rise apartments leading to loss of lives. In Malaysia, landslides are natural degradation processes that are mostly influenced by heavy rain because of either successive days of moderate rain or a single heavy rain or thunderstorm causing flash floods during rainy season, and then causing rock surface failure along the cleavage, fracture planes and joint planes (Sin and Chan, 2004). Rainfall following by the sliding movement of underground water greatly affects stability of slope. An alteration in the soil's moisture content is caused by rainfall. The pressure of interstitial pore, soil weight and seepage pressure increases while the cohesion reduces when there is change in the soil's moisture content. Thus, the slide mechanism is triggered by the heavy boulders of the soil mass. Recently, there is increase in the occurrence of landslides which can be related to land clearing and urban development in mountainous areas. Although, the country's geology is stable and adaptable, the continuous urbanization and development are leading to weathering, deforestation, and erosion of the covered soil masses leading to serious damage to the topography.

Moreover, Malaysia regularly incurred losses and damages because from the history, there was little attention given to possible challenge in the slope management and land use planning. Greater sensitizations on the problem of landslides have led to important change in the control of developments on areas with unstable slopes in the recent years. Also, authorities in care of airways and the government of Malaysia have been clamoring for the planning authorities in local communities to take responsibility of giving awareness on landslide account at all levels of hazard mapping progress. Regrettably, only few steps have been taken to make prediction of landslide and make prevention or warning on the damage they cause. From the scientific perspective, there are three stages on the analysis of landslide susceptibility (Varnes, 1984): the susceptibility, the possibility or hazard and the risk. The function of landslide and its causative factors in equation one and two are called susceptibility while hazard is the function of susceptibility and associated triggering factors. Those factors are described as the external forces like rainfall and earthquake. Rainfall data from the historical record are joined with the susceptibility map in order to map out the hazard region.

The damage caused by landslide can be greatly curbed to some extent though this kind of prediction model. In spite of that, some assumptions are made such as the statement that "the landscape under study is continuum of small units on which the models are valid in order to spatialize the any other uni-dimensional and statistically based-prediction models according to the measurements made on small portions. This can be applicable to homogenous soil types or land cover but this less apparent for fragmented landscape that contain mosaic of units behaving on landslides.

Only few researches have been previously done on landslide risk and hazard analyses on Penang Island. Some interesting case studies are presented by Toh (1999) on Penang Island on remedial and preventive work for rock-falls comprising granite boulders as in the case of cables, rock anchors, fences, wire nets and the concreting of loose boulders together. Some of these preventive ways may not be practicable or feasible form the study where many boulders show in the field. Then, Lee S. and Pradhan (2007) investigated using analytical study on the landslide risk and hazard on Penang Island using a statistically-based frequency ratio model. The study further extended the analysis of the hazard using ANN and logistic regression model to examine the most relevant outcomes for the area of study. The study aimed to analyze in details the hazard in area of Penang by applying three distinctive models for assessment to know which of the model best suit the statistical model of the study. Three procedural steps namely data mining, ANN and logistic regression were used for determination of rating and weight in the analysis of landslide hazard.

The intense and incessant rainfall was the causative factor that does trigger many slope failures and slides along the road section and surrounding areas. During the monsoon of 2006, this situation was further worsened for several

weeks leading to blockage of traffic. In order to reduce the loss of lives and value of economy, areas that are potentially prone to landslide should be recognized and identified. In this manner, the analysis of landslide susceptibility can give reliable information needed to reducing hazard via implementation and organizing of proper projects.

Furthermore, susceptibility of landslide is described as the possibility of landslide to occur in a region on the basis of local terrain condition (Brabb, 1984). In other word, it is a degree at which a terrain can be tampered by the movement of the slope; that is, an estimation of “where” landslide is closely to happen. In these present days, the introduction of GIS and remote sensing has made mapping easier for landslide susceptibility (Bednarik *et al.*, 2012). In the last decade, different ways to prepare hazard maps and landslide susceptibility using GIS tools and statistical methods were developed (Guzzetti *et al.*, 2005). In the literatures, the commonest statistical approaches and techniques proposed are: logistic regression; multivariate and bivariate (Bednarik *et al.*, 2010), (Pradhan, 2010). Other methods proposed by several investigators are: weighted linear combinations of instability factors and weighting factors (Ayalew *et al.*, 2004); modified Bayesian estimation (Chung and Fabbri, 1999); certainty factors (Pourghasemi *et al.*, 2012); landslide nominal risk factors (Saha *et al.*, 2005); methods of weights-of-evidence (Neuhauser and Terhorst, 2007); values of information (Saha *et al.*, 2005); and probabilistic-based frequency ratio model (Pradhan *et al.*, 2012).

In Malaysia, landslides have always posed a huge threat to structures and settlements that support tourism, natural resources and transportation; many considerable damages are caused to livestock, pipelines, properties, waterways and highways. In most cases, these landslides occurred on embankments or cut slopes alongside the highways or roads in mountainous areas. Landslides also occurred in other sides near residential areas and high-rise apartment leading to loss of human lives. According to a recent news report by a local newspaper, heavy rainfall have triggered mud flows and landslides in 2006 to 2009 along east coast highways in peninsular Malaysia, Sabah (East Malaysia) and in the island state of Penang. The most significant hit areas are along Cameron highland in the mountainous states of Pahang of peninsular Malaysia. These landslides caused loss of lives and cost nearly millions of dollars of property loss. If there is a long-term early warning system predicting the occurrences of landslides in the prone areas, the gravity of damages could have been minimized or reduced.

In the year 2003, the governmental organizations and other highway authorities have been alerted towards the importance of prevention and management of landslides due to the occurrence of landslides in the New Klang Valley Express Highways region. The landslide that occurred in October 2002 around Kuala Lumpur that destroyed few houses completely and took the lives of six members of a family is still fresh in the memory of people. Flash floods and tropical rainfall mainly triggers the landslides occurrence in Malaysia leading to less cohesion of the rock surface along joint, cleavage and fracture planes. The continuous urbanization and development leads to erosion, weathering and deforestation of the covered soil masses resulting to serious threat to slopes although the geology of the country is still stable. In mountainous terrain, earthquakes are the major causes of landslide. Unlike Japan, where earthquakes occur every hour, Malaysia is not seismically active. In spite that, earthquake-prone areas surrounds Malaysia and there is often the possibility of mild shocks being transmitted as recently experienced in the years 2006, 2008 and 2009 in western parts of Peninsular Malaysia.

The frequent occurrence of landslide in Malaysia is due to heavy rainfall. Recently, there have been significant changes in the control of development on unstable land with the highway authorities and Malaysian government stressing the need for local planning authorities to take mapping of landslide susceptibility into consideration at all levels of developmental and planning process. Thus, to predict and prevent the damages caused by landslides, only few attempts have been made. Landslide can be greatly minimized through a prediction model and through scientific analysis, assessment and prediction of landslide-susceptible areas can be achieved which can reduce the damages of landslide from adequate preparation. For this objective to be achieved, susceptibility analysis of the landslide has been carried out and verified in the study using artificial neural network.

Also, Lee S and Talib (2005) investigated the use and validation of logistic regression model for mapping of landslide susceptibility using remote sensing data or GIS. In the recent years in Malaysia, there has been increase in landslide occurrence while most of the landslides occurred on embankment and cut slopes alongside highways and roads in mountainous areas. Many people experienced great anxiety due to the occurrence of some of these landslides near residential areas and high-rise apartments. Within the last years, a few catastrophic and major landslides have also occurred. The landslides have caused significant damages in terms of property loss and loss of lives. In each of this occasion, much damage is caused in Penang in Malaysia being the considered area of this study. The most common landslides are the ones triggered by a heavy rainfall but only few studies made an attempt to suggest the best predictive or preventive model against the damages. To find solution to this challenge, it is a must to investigate the scientific factors that lead to landslide. Therefore, decrease in landslide damage can be decreased. By employing scientific analysis of landslide, landslide-susceptible areas can be assessed and predicted; through adequate preparation, this can decrease the damage incurred by landslide. To achieve the aim of this study, landslide-related factors were assessed; the analysis techniques of landslide susceptibility have also been verified and identified.

The areas of Penang have suffered a lot of damages from landslide due to heavy rains; therefore, the area is suitable to evaluate the distribution and frequency of landslides. Penang is known as one of the thirteen states in the Federation of Malaysia. Many studies have been carried out on the evaluation of landslide hazard using GIS. For example, Guzzetti *et al.* (1999) made a summary of evaluation studies of landslide disasters. In the recent time, using GIS, there have been studies on landslide disaster and some of these studies employed probabilistic methods (Donati and Turrini, 2002), (Lee S. and Choi, 2003), (Zhou C. H. *et al.*, 2002). The logistic method being one of the

statistical methods available has also been applied to land disaster mapping (Ohlmacher and Davis, 2003) and in some cases, the safety factor and geotechnical methods (De *et al.*, 2003), (Zhou G. *et al.*, 2003). According to Ercanoglu and Gokceoglu (2002) and Pistocchi *et al.* (2002), artificial neural network and data mining using fuzzy logic methods as new approaches to landslide disaster evaluation using GIS have been applied. Landslide is a one kind complicated, large-scale and dangerous natural disaster; however, there are some laws in the occurrence of the landslides. One of the most important tasks of geospatial information technology is the dynamic monitoring of landslides using remote sensing, then foretelling and forecasting the disasters and making precautions.

In another vein, Pradhan and Youssef (2010) studied the assessment and correlation of soil erosion with landslide occurrence using GIS and remote sensing data – a case study of Penang Island in Malaysia. In Penang, Malaysia, land is a scarce resource which is much sought after. This is a result of Penang Island being largely made up of steep topography including hilly areas as most of the lowland areas are developed already. One of the fast-rising industrialized states is Penang in Malaysia with a relative large urban population. In the past decades, the development of other economic sectors and industrialization efforts have been intensified, resulting to pressure on the land from greater urbanization. Despite the reduction in the pressure through land reclamation, yet it cannot suffice the high demand of land on the island.

The high rates of erosion occurrences causing environmental disaster in many parts of the hill slopes in Penang Island was due hill land development. This has led to landslides in the last decades (Pradhan and Youssef, 2010). Goh (1982) stated that the natural elements particularly the weather elements are highly corrosive in Penang Island. Geomorphological processes such as surface run-off erosion and rain splash erosion have been identified to be extremely high in the wet equatorial areas (Pradhan, 2010). The erosivity of run-off and rain are the main causes of soil loosening, weakening slopes given the high intensity of tropical rainfall within short durations which leads to mass movements of solids and semi-solid materials such as landslips, landslides and soil creep (Brunsdon and Prior, 1984), (Lim and Lee, 1992). Deforestation occurring in hilly areas especially steep slopes more than 20 degree can trigger landslides and erosions.

When deforestation is controlled along with immediate replanting, landslides and erosion can be minimized but when it is implemented at a rapid rate that is non-sustainable, it can lead to landslides and weaken the slopes. According to Chan (1998), deforestation is relatively close to hill development as before hills are developed, they are densely forested. Moreover, the squatters built the unpaved roads to improve accessibility; many people also illegally farm on the slope (Pradhan, 2010). All these activities have exposed steep slopes to erosion and destroyed the natural forest cover. Also, highway construction through the dense equatorial forests has been a major cause of landslides and soil erosion. Numerous minor landslides also have been reported along highways in Malaysia before the occurrence of major ones along the north-south highway near Bukit Lanjan in 21 October, 2003 in Kuala Lumpur (Pradhan, 2010).

In this area, the main cause of land sliding is soil erosion; it is essential to be controlled in order to avert landslides. The rate of soil erosion can be reduced by moderating the factors which are determinants to soil erosion such as land cover and land use. Due to this, the Penang Island is continuously under pressure for various urban and agricultural developments. As a result, this has led to environmental problems such as: water pollution; downstream flooding; decimation of water catchments, deforestation, soil erosion, destruction of endangered flora and fauna, sedimentation and landslides (Ahmad *et al.*, 2006). Basically, this study will explore modelling disasters occurrences in order to suggest a reliable predictive and preventive model against the huge impact of natural disasters in Malaysia. Hence, the general objectives of the study are segmented into threefold as follow:

- i. To identify the meteorological factors that causes landslide natural disaster occurrences in Penang, Malaysia;
- ii. To compare the prediction performance of different predictive models; and
- iii. To suggest a predictive model for landslide disaster occurrence in Penang, Malaysia.

The changes in the earth's meteorological conditions are at a rate that beat scientific imaginations. The changes are greatly affecting the global average temperature to increase to extreme temperatures which are causing the occurrence of natural disasters such as landslide. According to the Internal Displacement Monitoring Centre (IDMC) report of 2015, there are over 22.5 million individuals displaced since 2009 to 2015 as a result of natural disaster events worldwide. This figure by IDMC is still growing daily most especially in Malaysia that is prompt to both landslide and flood natural disaster occurrences. Although, there have been many models to predict and forecast these landslide natural disaster occurrences particularly in Malaysia such as Koay *et al.* (2016) and Pradhan *et al.* (2012). These studies have the ability to predict landslide natural disaster occurrences to a large extent; however, scholars are concerned with the efficiency and predictability of these models due to the changes in earth's meteorological conditions as a result of climatic changes (Stähli *et al.*, 2015). Thus, the need for a predictive model for occurrence of landslide natural disaster is imperative to the safety of lives and protection of both environmental and economy of the region. In summary, the problem statements of this study are: Lack of disaster occurrence system in Malaysia; Lack of Real-time info to guide disaster response agencies operations in Malaysia. Climatic change has caused changes in metrological parameters which have influence on existing predictive models. Therefore, this study will propose a predictive model of landslide disaster occurrence in Malaysia.

### 3. Methodology

#### 3.1. Predictive Model

In previous studies, researchers implemented various methods in prediction such as fuzzy logic (Saleh and Kim, 2009), case-based reasoning (CBR) (Kaur and Sharma, 2015), support vector machines (SVM) (Park and Kim,



2013), regression analysis (Chan, 1998), decision trees (Chien *et al.*, 2007), (Wang, 2007) and artificial neural networks (ANN) (Ali A. *et al.*, 2014), (Turban *et al.*, 2011). Fuzzy logic has limitation where it is hard to supply membership information by experts or people (Carbonneau *et al.*, 2007), while CBR is difficult in representing case among different types of cases (Carbonneau *et al.*, 2007), (Park and Kim, 2013) and SVM less compatible due to limitation in achieving true generalization (Lee S. and Pradhan, 2006) and development, training and testing of the method tend to be time consuming (Carbonneau *et al.*, 2007; Turban *et al.*, 2011). On the other hand, regression analysis which is a traditional forecasting method shows low performance for data mining process (Carbonneau *et al.*, 2007) while decision trees only best to be applied when the number of classes is low (Wang, 2007) and for classification purpose (Chien *et al.*, 2007). However, in many cases, ANN shows capability in prediction due to its ability to capture the underlying structural relations among various variables. Moreover, ANN is a nonlinear data driven and self-adaptive approach (Carbonneau *et al.*, 2007), (Turban *et al.*, 2011). Therefore, it is recommended to explore the capability of ANN in predicting the occurrence of landslide as the method has been proved to solve many prediction problems.

### 3.2. Research Scope

The main focus of this study is to suggest a formal model of landslide disaster occurrences in Malaysia. Specifically, the study can be seen in two different viewpoints namely identification of factors responsible for landslide disaster occurrences and predictive model for landslide disaster occurrences in Malaysia. This study will only make use of data from meteorological only whereas factors like seismic and geological will not be considered in this present study.

### 3.3. Study Area

With the land clearing for hostels, apartments and hotels resulting to landslides and erosion, rapid developments is occurring to Penang Island. Penang is located in the Northwest coast of the peninsula, Malaysia and it is one of the 13 states of the federal territory of Malaysia. Penang is bound to the West by the straits of Malacca and Sumatra in Indonesia, by the state of Perak in the South and by the state of Kedah in the North and East. The state consists of a coastal strip on the mainland known as Province Wellesley and island of Penang. The island is separated from the mainland by a channel and it covers an area of 285km<sup>2</sup>. This area of study is located approximately between latitude 5°15'N to 5°30' N and longitude 100°10' E to 100°20' E. The area's slope ranges between 25° and 87°. The area of the study consists of hills, mountains and coastal plains and its relief varies between 0 and 420m above the mean sea level (msl). Throughout the year, the rainfall evenly distributed with more occurrence of rain from September to November. The bedrock geology of the study area mainly consists of granite. Also, the population of Penang is approximately one million people. The data from Malaysian Meteorological Department states that the temperature ranges between 29°C and 32°C in the northern part of Penang and the mean relative humidity ranges between 65 per cent and 70 per cent. The mean relative humidity is lowest in June, July and September while the highest temperature occurs between April and June. The average rainfall on Penang Island ranges from 58.6 to 240mm and 2,670 to 6,240mm per month and annum respectively.

## 4. Conclusion

This study proposes ANN as the predictive model for the occurrences of landslide natural disaster. The contribution of this study can be viewed in two different perspectives namely theoretical and practical contributions. This study theoretical contribution can be seen from two distinct perspectives. The first theoretical contribution is the determination of factors of meteorological that causes landslide disaster occurrences. This will enlighten disaster management agencies to identify important factors that are needed for occurrence of disasters in order to prevent against loss of lives and properties. The second theoretical contribution is the predictive model that will forecast landslide disaster occurrences. This will pinpoint volatile regions that are likely to experience landslide disasters in order for agencies to take preparative actions to prevent and avoid huge calamities. The practical contribution of this study is the proposed predictive simulator which will depict the influence of each factor in the occurrence of landslide disasters. ANN shows capability in prediction due to its ability to capture the underlying structural relations among various variables. Also, ANN is a nonlinear data driven and self-adaptive approach (Carbonneau *et al.*, 2007), (Turban *et al.*, 2011). Therefore, it is recommended to explore the capability of ANN in predicting the occurrence of landslide as the method has been proved to solve many prediction problems. This study will further broaden the understanding of how the identified meteorological factors causing landslide disaster occurrences in Malaysia affect environment and human interaction. The understanding of these factors will serve as core components in scientific reasoning for the occurrence of landslide disaster in Malaysia

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